CLAIMS

I claim:

1.   A method of relieving congestion in a packet-based

network that interconnects a plurality of peripheral networks

by implementing corrective actions in said peripheral

networks, said peripheral networks each comprising a plurality

of switches, and said packet-based network comprising a

plurality of gateway nodes having data to be transferred

therebetween, and utilizing a concept of virtual pipelines

between said gateway nodes, said pipelines comprising one or

more channels, said method comprising the steps of:

     (1) identifying a first set of virtual pipelines for

which traffic exceeds a predetermined threshold;

     (2) for each virtual pipeline in said set, determining a

number of additional channels needed to cause said traffic

through said pipeline to not exceed said predetermined

threshold; and

     (3) for each pipeline in said first set, assigning a

corrective action and an amount of said corrective action to

be taken in said peripheral networks as a function of said

number of additional channels.

2.   The method set forth in claim 1 wherein step (3)

comprises the steps of assigning a call gapping rate for each

switch in the peripheral network contributing traffic to a

pipeline for which traffic exceeds said predetermined

threshold.

3.   The method set forth in claim 2 wherein said call

gapping rates are

$$\lambda t - \lambda_N) / \lambda_t$$

where

λt is a call arrival rate for a corresponding pipeline;

and

λ_N is a call arrival rate corresponding to said

predetermined threshold for said corresponding pipeline.

4.   The method set forth in claim 3 wherein said

predetermined threshold is a call blocking ratio and wherein

step (2) comprises determining a minimum pipeline size that

would reduce the call blocking ratio for said pipeline below

said predetermined threshold based on a call arrival rate at

said virtual pipeline and an average holding time per call.

5.   The method set forth in claim 4 wherein said minimum

pipeline size is expressed as a number of channels, M, in said

pipeline and wherein step (2) comprises determining a number

of channels M by;

$$B_M (\lambda_i / \mu) = \frac{(\lambda_i / \mu)^M / M!}{\sum_{n=0}^{M} (\lambda_i / \mu)^n / n!}$$

wherein

$$\rho(t) = \lambda((t) / \mu(t)$$

or

$$\rho'(t) = \lambda(t) - \rho(t) / \mu(t)$$

6. The method set forth in claim 5 wherein

$\rho(t) = \lambda((t) / \mu(t)$ is used when call rate through said

pipeline has been historically increasing and

$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$ is used when call rate through said

pipeline has been historically decreasing.

7. The method set forth in claim 4 wherein said network

is an asynchronous transfer mode network.

8. The method set forth in claim 7 wherein said network

is used to exchange voice data.

9. The method set forth in claim 8 wherein said other

networks comprises time division multiplexed networks.

10.   The method set forth in claim 1 wherein said

corrective action comprises rerouting calls in said peripheral

networks that would so that they pass through a different

pipeline in said packet-based network.

11.   The method set forth in claim 10 wherein said

predetermined threshold is a call blocking ratio and wherein

step (2) comprises determining a minimum pipeline size that

would reduce the call blocking ratio for said pipeline below

said predetermined threshold based on call arrival rate at

said virtual pipeline and average holding time per call.

12.   The method set forth in claim 11 wherein said

minimum pipeline size is expressed as a number of channels, M,

in said pipeline and wherein step (2) comprises determining a

number of channels M by;

$$B_M(\lambda_i / \mu) = \frac{(\lambda_i / \mu)^M / M!}{\sum_{n=0}^{M} (\lambda_i / \mu)^n / n!}$$

wherein

$\rho(t) = \lambda((t) / \mu(t)$

or

$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$

13.   The method set forth in claim 11 wherein said
network comprises a plurality of gateway nodes through which
calls in said peripheral networks enter and exit said packet-
based network and wherein step (3) comprises the steps of:

5   (3.1)   determining a peak cell rate corresponding
to said number of additional channels;

           (3.2)   determining if there is at least one
gateway node corresponding to a source peripheral network for
which there exists a path in said packet-based network to a
10 destination node of said pipeline;

           (3.3)   determining if said path can accommodate a
pipeline having said peak cell rate; and

           (3.4)   generating data indicating one or more
alternate source gateways.

15   14.   The method set forth in claim 13 further comprising
the step of:

           (3.5)   outputting said data to said peripheral
networks.

20   15.   The method set forth in claim 13 further comprising
the step of:

     (4) organizing prior to step (3) said pipelines
identified in step (1) in order of said number of additional
channels determined in step (2); and

wherein steps (3.1), (3.2), (3.3), (3.4) and (3.5)

are performed for each pipeline identified in step (1) in

order from said pipeline corresponding to said highest number

of additional channels to said lowest number of additional

5   channels.

16.   The method set forth in claim 15 wherein step (3.2)

comprises creating a list of all gateway nodes and wherein

step (3.3) is performed with respect to each source gateway in

said list of gateways until a source gateway having a path to

10   said destination gateway that can accommodate a pipeline

having said peak cell rate is located.

17.   An apparatus for relieving congestion in a packet-

based network that interconnects a plurality of peripheral

networks by implementing corrective actions in said network,

15   said packet-based network comprising a plurality of gateway

nodes having data to be transferred therebetween, and

utilizing a concept of virtual pipelines between gateway nodes

of said network, said pipelines comprising one or more

channels, said method comprising the steps of:

20   means for identifying a first set of virtual pipelines

for which traffic exceeds a predetermined threshold;

          means for determining, for each virtual pipeline in said

set, a number of additional channels needed to cause said

traffic through said pipeline to not exceed said predetermined
threshold; and

   means for assigning, for each pipeline in said first set,
a corrective action and an amount of said corrective action to
be taken in said peripheral networks as a function of said
number of additional channels.

   18.   The apparatus set forth in claim 17 wherein said
means for assigning comprises:

   means for assigning a call gapping rate for each
peripheral network contributing traffic to a pipeline for
which traffic exceeds said predetermined threshold.

   19.   The apparatus set forth in claim 18 wherein said
call gapping rates are

$$\frac{\lambda_t - \lambda_N}{\lambda_t}$$

where

   λ_t is a call arrival rate for a corresponding pipeline;

and

   λ_N is a call arrival rate corresponding to said

predetermined threshold for said corresponding pipeline.

20. The apparatus set forth in claim 19 wherein said predetermined threshold is a call blocking ratio and wherein said means for determining comprises determining a minimum pipeline size that would reduce the call blocking ratio for

5   said pipeline below said predetermined threshold based on a call arrival rate at said virtual pipeline and an average holding time per call.

21. The apparatus set forth in claim 20 wherein said minimum pipeline size is expressed as a number of channels, M,

10   in said pipeline and wherein step (2) comprises determining a number of channels M by;

$$B_M(\lambda_i / \mu) = \frac{(\lambda_i / \mu)^M / M!}{\sum_{n=0}^{M} (\lambda_i / \mu)^n / n!}$$

wherein

$$\rho(t) = \lambda((t) / \mu(t)$$

15   or

$$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$$

22. The apparatus set forth in claim 21 wherein $\rho(t) = \lambda((t) / \mu(t)$ is used when call rate through said pipeline has been historically increasing and

$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$ is used when call rate through said

pipeline has been historically decreasing.

23. The apparatus set forth in claim 20 wherein said
network is an asynchronous transfer mode network.

24. The apparatus set forth in claim 23 wherein said
network is used to exchange voice data.

25. The apparatus set forth in claim 24 wherein said
other networks comprises time division multiplexed networks.

26. The apparatus set forth in claim 17 wherein said
corrective action comprises rerouting calls in said peripheral
networks so that they pass through a different pipeline in
said packet-based network.

27. The apparatus set forth in claim 26 wherein said
predetermined threshold is a call blocking ratio and wherein
said means for determining comprises determining a minimum
pipeline size that would reduce the call blocking ratio for
said pipeline below said predetermined threshold based on call
arrival rate at said virtual pipeline and average holding time
per call.

28.   The apparatus set forth in claim 27 wherein said

minimum pipeline size is expressed as a number of channels, M,

in said pipeline and wherein step (2) comprises determining a

number of channels M by;

5

$$B_M (\lambda_i / \mu) = \frac{(\lambda_i / \mu)^M / M!}{\sum_{n=0}^{M} (\lambda_i / \mu)^n / n!}$$

wherein

$$\rho(t) = \lambda((t) / \mu(t)$$

or

$$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$$

29.   The apparatus set forth in claim 27 wherein said

network comprises a plurality of gateway nodes through which

calls in said peripheral networks enter and exit said packet-

based network and wherein said means for assigning comprises:

          means for determining a peak cell rate corresponding

15   to said number of additional channels;

          means for determining if there is at least one

gateway node corresponding to a source peripheral network for

which there exists a path in said packet-based network to a

destination node of said pipeline;

20   means for determining if said path can accommodate a

pipeline having said peak cell rate; and

means for generating data indicating one or more

alternate source gateways.

30.   The apparatus set forth in claim 29 further

comprising:

means for outputting said data to said peripheral

networks.

31.   The apparatus set forth in claim 29 further

comprising:

means for organizing said pipelines identified by said

means for identifying said first set of virtual pipelines in

order of said number of additional channels determined by said

means for identifying; and

wherein said means for assigning acts on each pipeline

identified by said means for identifying said first set of

virtual pipelines in order from said pipeline corresponding to

said highest number of additional channels to said lowest

number of additional channels.

32.   The apparatus set forth in claim 31 wherein said

means for determining if there is at least said one gateway

node comprises means for creating a list of all gateway nodes

and wherein said means for determining if said path can

accommodate a pipeline having said peak cell rate acts upon

each source gateway in said list of gateways until a source

gateway having a path to said destination gateway that can
accommodate a pipeline having said peak cell rate is located.

33. A method of relieving congestion in a packet-based
network that interconnects a plurality of peripheral networks
5   by implementing corrective actions in said peripheral
networks, said packet-based network comprising a plurality of
nodes through which calls pass, said plurality of nodes
including gateway nodes through which calls enter said packet-
based network from said peripheral networks and exit said
10 packet-based network to said peripheral networks, said method
comprising the steps of:

(1) identifying a set of pairs of gateway nodes
contributing traffic to individual ports of said packet-based
network that are experiencing congestion above a predetermined
15 threshold;

(2) for each pair of gateway nodes identified in
step (1), assigning a bandwidth correction factor as a
function of a fraction of calls between said pair of gateway
nodes that would need to be blocked to meet said threshold for
20 a port to which that pair of gateway nodes is contributing
traffic that is most congested;

(3) for each pair of gateway nodes identified in
step (1), assigning a corrective action and an amount of said
corrective action to be taken in said peripheral networks as a
25 function of said bandwidth correction factor.

34.   The method set forth in claim 33 wherein step (3)

comprises the steps of assigning a call gapping rate for each

peripheral network contributing traffic to a port for which

traffic exceeds said predetermined threshold.

5   35.   The method set forth in claim 34 wherein said call

gapping rates are

$$\frac{(\lambda_t - \lambda_N}{\lambda_t}$$

where

λ_t is a call arrival rate for a corresponding pipeline;

10   and

λ_N is a call arrival rate corresponding to said

predetermined threshold for said corresponding pipeline.

36.   The method set forth in claim 33 wherein step (1)

15   comprises the steps of:

        (1.1)   comparing a present utilization of each

port to a utilization threshold; and

        (1.2)   for each port with present utilization

exceeding said threshold, finding a set of pairs of gateway

20   nodes contributing calls through said port.

37.   The method set forth in claim 36 wherein said
threshold comprises a delay jitter parameter.

38.   The method set forth in claim 36 wherein said
threshold comprises a packet loss parameter.

39.   The method set forth in claim 36 wherein said
threshold comprises a delay jitter parameter and a packet loss
parameter.

40.   The method set forth in claim 36 wherein step (3)
comprises:

        (3.1) for each port identified in step (2),
determining the number of calls per second that can be
accommodated at said port without exceeding said threshold;

        (3.2) for each port identified in step (2),
determining the ratio by which the actual number of calls per
second through said port exceeds said threshold; and

        (3.3) for each pair of gateway nodes that is
contributing traffic to at least one congested port, assigning
to said pair of gateway nodes a voice compression ratio
corresponding to the port to which it is contributing traffic
that is most congested.

41.   The method set forth in claim 40 wherein step (3.1)
comprises solving:

$$T = \frac{(\alpha_c / \mu)^C / C!}{\displaystyle\sum_{n=0}^{C} (\alpha_c / \mu)^n / n!}$$

for α_c, where

C is a number of calls that can be accommodated at the port as

determined by said threshold,

$1/\mu$ is an average holding time per call, and

α_c is said number of calls per second that can be accommodated

at that port.

42. The method set forth in claim 41 wherein step (3.2)

comprises the step of solving

$$\alpha_A = \sum_{j=0}^{M} \lambda_{Ri,j}$$

where α_A is an average arrival rate for calls between pairs of

nodes in said set of gateway nodes contributing traffic to

said port.

43. The method set forth in claim 42 wherein said

bandwidth correction factor are derived by

$$\rho_{B,} = (\alpha_A - \alpha_c) / \alpha_A$$

where ρ_{BL} is said bandwidth correction factor.

44.   The method set forth in claim 33 wherein said

corrective action comprises re-routing calls in said

peripheral networks.

5   45.   The method set forth in claim 44 wherein step (3)

comprises the steps of:

(3.1)   for each pair of gateway nodes identified

in step 1, determining a number of extra channels needed to

reduce traffic below said threshold;

10   (3.2)   determining if there is at least one

gateway node corresponding to a source peripheral network for

which there exists a path in said packet-based network to a

destination node of said pipeline;

(3.3)   determining if all ports through which

15   said path traverses have present utilization less than their

utilization thresholds.

(3.4)   generating data indicating one or more

alternate source gateways.

46.   The method set forth in claim 45 further comprising

20   the steps of:

(3.5)   outputting said data to said peripheral

networks.

47. The method set forth in claim 46 further comprising
the step of:

(4) ordering prior to step (3), said pipelines identified
in step (1) in order of said number of extra channels

5   determined in step (2); and

wherein steps (3.1), (3.2), (3.3), (3.4) and (3.5)
are performed for each pipeline identified in step (1) in
order from said pipeline corresponding to said highest number
of extra channels to said lowest number of extra channels.

48. The method set forth in claim 47 wherein step (3.2)

10   comprises creating a list of all gateway nodes and wherein
step (3.3), (3.4) and (3.5) are performed for each path in
said list created in step (3.2).